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Preliminary Evaluation of Anchoring Furniture and Televisions Without Tools

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Editor's Note

Dr. Jonathan Midgett was the primary author and progenitor of this report.[1] He was employed as a member of U.S. Consumer Product Safety Commission ("CPSC") Office of Hazard Identification and Reduction (EXHR) staff during the research and authorship of the first draft. The timing of the internal CPSC staff review and clearance of the report coincided with Dr. Midgett leaving EXHR staff and being appointed a special assistant in the office of CPSC Chairman Kaye. Final edits and changes to the document were made exclusively by Mr. John Massale, Mr. Randy Butturini, and Mr. Scott Snyder.

[1] This report was produced by CPSC staff, and has not been reviewed or approved by, and may not necessarily reflect the views of, the commission

Part I - Introduction and Background

Project Goals

The primary goal of this project is to demonstrate the effectiveness of anchoring systems that can be installed either without tools or with minimal consumer effort. Diminishing or eliminating the need for tools makes anchoring easier, faster, less expensive, and more commonplace. The second goal of this report is to facilitate a forum for public education and discussion. Surviving victims and advocates of deceased victims, along with manufacturers, voluntary standard organizations, and other stakeholders, could have an opportunity to share personal stories and best practices with uneducated consumers to effect injury prevention. Third, this project aims to stimulate creative problem solving efforts by highlighting the viability of simple, low-cost solutions. These raw ideas span current restraint methods as well as market gaps for consumers with different anchoring needs. Finally, the organizations that develop voluntary standards for furniture may consider proposing more options for anchoring systems to include in relevant standards.

The Known Hazard

Falling furniture, electronics, and appliances caused at least 363 fatalities in the United States from 2000 through 2011[2]. About 82 percent of victims in these reported 363 fatal incidents were younger than 8 years. Emergency department-treated injuries associated with product instability have been estimated to occur at a rate of 38,000 per year (all ages). The majority of all falling furniture incidents, injuries, and estimated fatalities occurred in consumers' homes. Head injuries, injuries from being crushed under falling electronics or by tipped over furniture and appliances, constitute the most common injuries. The basic mechanical properties of furniture stability are explored in Appendix A.

Regarding the types of furniture, electronics, and appliances involved in the 363 reported fatalities, 62 percent (226 deaths) involved televisions falling. Ninety-two of the 226 fatalities were associated with televisions falling at the same time as the furniture on which the television was resting. Thirty percent (109 deaths) of the 363 reported fatalities were associated with only furniture falling. The remaining 8 percent (28 deaths) of the 363 reported fatalities involved appliances tipping over.

As for the victim age distribution, of the 363 reported fatalities, 303 involved children ranging in age from 1 month to 10 years. Sixty-five percent (198 deaths) of the children were at least 1 year of age and less than 3½ years of age. Sixty-seven victims were between 3½ years of age and less than 6½ years of age. Thirteen victims were between 6½ and 8½ years of age.

[2] Gipson and Suchy.

For the remainder of this report, unless otherwise stated, the terms "falling furniture" or "furniture" will be used to denote any type of clothing storage unit, bookcase, electronics, and appliances.

Existing Voluntary Standards

Televisions are required by UL 1492 to pass a stability test, but there is no requirement for restraint systems to be included with the television.

The current ASTM International ("ASTM") voluntary standard for furniture is *ASTM F2057-14, "Standard Safety Specification for Clothing Storage Units."*[3] The standard covers chest-type furniture and other clothing storage units taller than 30 inches. The standard addresses stability two ways. First, the standard has a freestanding requirement and two corresponding performance tests that specify that an unloaded unit shall not tip when all the drawers and doors are open to their full extension. The standard additionally specifies that a unit shall also not tip when one fully open drawer or door is loaded with a total weight of 50 lbs. Fifty pounds represents the weight of a 95^{th} percentile 5-year-old child. Second, the standard also requires a tip-restraint system with installation instructions that must be provided at the point of sale of the furniture.

ASTM F2057-14 states that the anchoring system must meet *ASTM F3096-14 Standard Performance Specification forTipover Restraint(s) Used with Clothing Storage Units*.[4] ASTM F3096 is a separate standard specifically for tip-restraint systems and states that they must withstand a pull force of 50 lbs., also based on the weight of the 95^{th} percentile 5-year-old child. However, the requirements of both F2057 and F3096 are confined to the restraint system. Neither standard includes a situational assessment of the connection points to the wall and/or furniture. This means that the strap securing a piece of furniture must be able to hold 50 lbs., but the drywall anchor that holds the strap to the wall has no strength requirement.

Many types of anchoring systems can be provided to meet the standard, but the typical anchoring system consists of screws and fabric straps that affix the furniture to the wall. One of the problems is that such restraint systems are not usually installed by consumers. This is evidenced by the reported tip-over incidents previously mentioned, as well as the results of a 2010 consumer opinion survey.

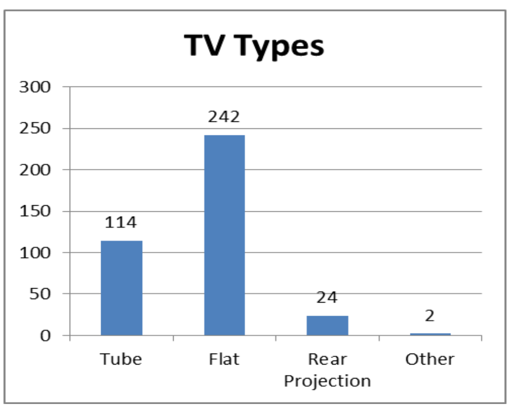
[3] ASTM International.
[4] ASTM International.

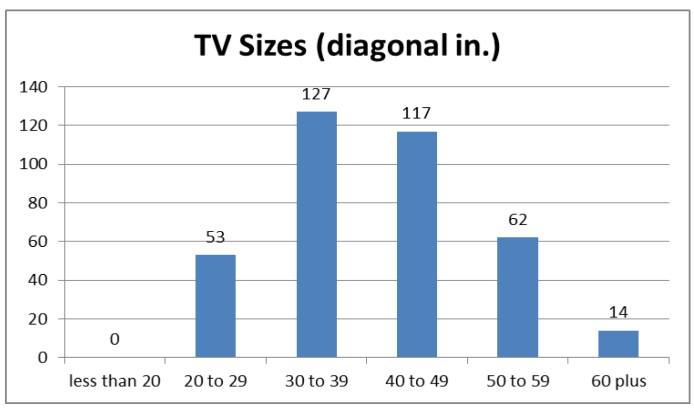
Consumer Opinion Forum Survey

CPSC staff formerly maintained a listserv for consumer volunteers who are willing to take brief surveys about safety habits in their homes or other product-related questions. The list was part of the Consumer Opinion Forum, which is no longer an active project. In 2010, staff sent a survey link about television anchoring to all of the listserv members. The 388 respondents provided information about the largest television in their homes. This was not a random sample of the national population and cannot be used for statistical inferences. The consumers volunteering to respond to this survey were more likely to be safety conscious than a random sample of consumers based on their use of the CPSC website and expressed willingness to convey information about safety habits. Nevertheless, because their responses were apt to be skewed toward safe practices in the home, their replies could be viewed as a best-case scenario for a survey of safety habits. The results of this survey are informal and have not undergone peer-review; nor are the results statistically valid to make national projections of consumer behavior.

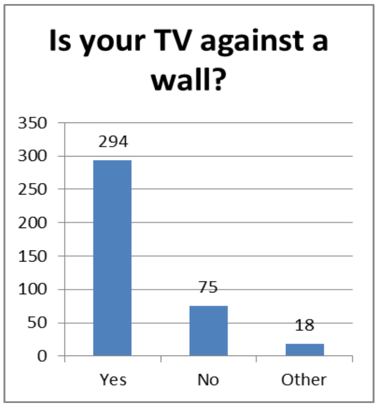
The average age of the respondents was 47 years old, with 270 (69 percent) reporting that they had at least one child. Ninety-one respondents (23 percent) had at least one child who was 6 years old or younger at the time of responding to the survey. One hundred eighteen (30 percent) respondents had no children.

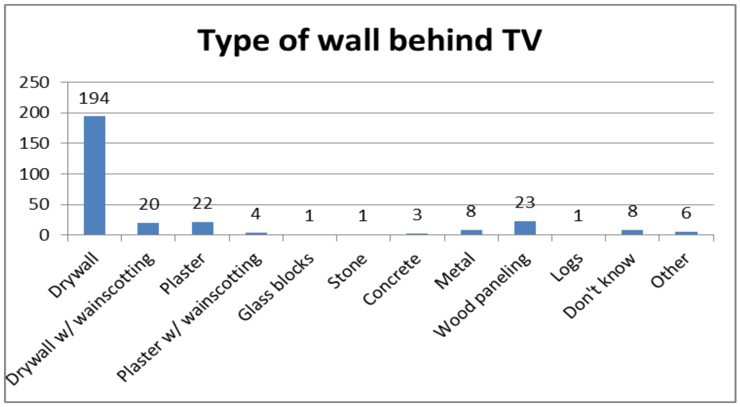
For this particular group of volunteers responding in 2010, 63 percent owned a flat screen television, and 30 percent owned a cathode ray tube television. Eighty-two percent owned televisions larger than 30 inches (diagonal dimension).



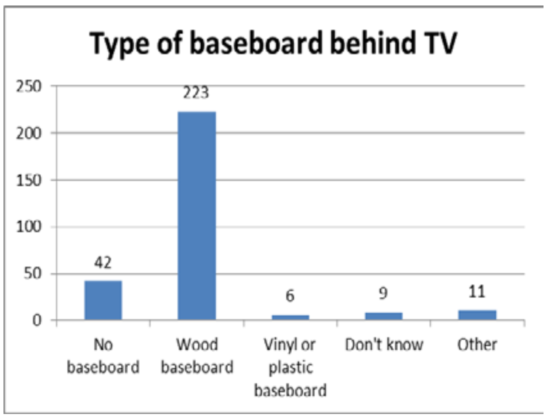


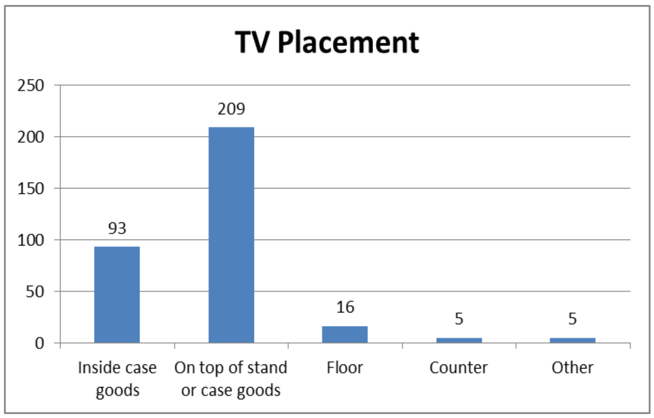
Ninety-five percent of volunteers had a wall behind their television. About two-thirds of these walls were drywall.



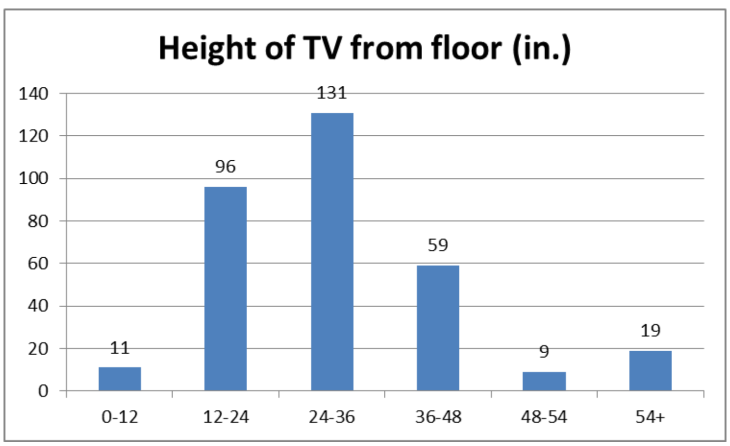


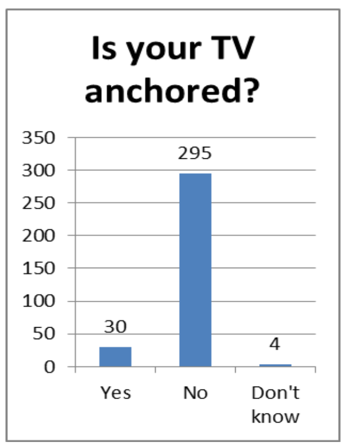
Most of the walls (77%) behind the television had wood baseboard trim. Most of the televisions were placed on top of some kind of furniture (64%).

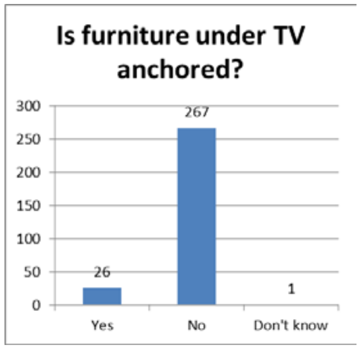




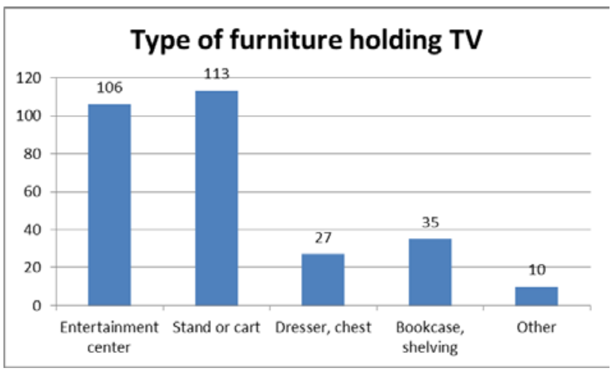
Televisions in this sample were usually placed between 1 foot and 3 feet above the floor. Very few televisions were anchored (only 9%).

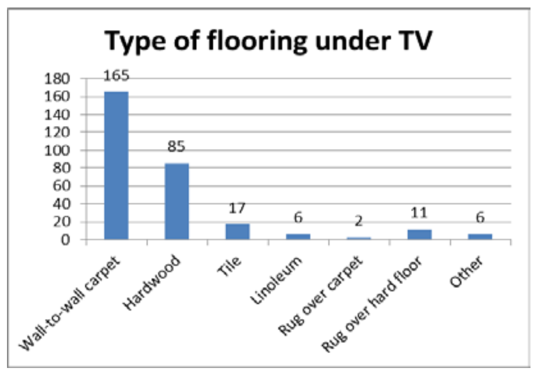




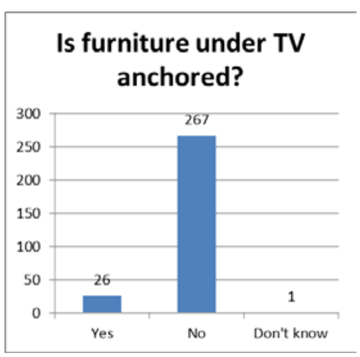


Entertainment centers and other television stands predominated the types of furniture holding televisions in the volunteers' homes. Many respondents had wall-to-wall carpeting in the room with the largest television.





Most consumers (91%) had not anchored the furniture that was holding their television.



Currently Available Solutions

An example of a typical anti-tip system currently provided is two screws with a short strip of woven synthetic fiber strap. The anti-tip system is usually intended for the consumer to attach the strap to the rear of the furniture with one screw; the strap then extends horizontally (or nearly so) to the wall, where it is attached with the second screw. Because of the strap's short length, the two connection points (furniture and wall) need to withstand the forces of an overloaded furniture pulling straight out (a perpendicular force) from the wall. For drywall anchors, this orientation of a pull force is the most difficult to withstand. Drywall anchors are strongest when pulled at an angle parallel to the wall (a shearing force). Because drywall cannot typically withstand a 50 lb. pull force, as required by the current voluntary standard, drywall anchors are not typically provided. Rather, a wood screw is usually provided and must be installed in a stud. This means that consumers will need a stud finder (or need to poke holes in the wall to determine the stud's location), a drill, a screwdriver, and several minutes of time.

Staff was unable to find any furniture anchors available for purchase that did not require tools for installation. At least one firm makes adhesive-backed anchoring systems for the stability of televisions and other electronics, but no one seems to market tool-less anchors for furniture stability. Typical tethers for furniture and televisions range from $6 to $10 per piece or for a pair. For the same amount of money, consumers could purchase 25 to 50 drywall anchors, 10 to 20 wire hooks, 4 to 8 adhesive-backed plastic hooks, or 3 to 6 self-tapping toggle bolts.

Staff identified many potential reasons why consumers may not anchor heavy furniture, televisions, and appliances. For example, consumers may be unaware of the hazards presented by common household products. Additionally, other consumers might predict the hazard of a product falling, but may not foresee the severity of the consequences. Still others may not desire holes in their walls or be allowed to make holes in their walls with an anchoring system because they rent their residence and would forfeit a damage deposit if they did so. In addition, some might value the ability to move their furniture without the added inconvenience of unfastening an anchor. Moreover, some might lack the necessary tools or skills for affixing anchors to their walls according to manufacturer instructions. Furthermore, the time and effort needed to do the job may also reduce the frequency of installing safety anchors among the general population.

Even small costs in terms of time, money, or inconvenience are likely to decrease the overall number of consumers who comply with safety imperatives. While the first choice for injury prevention is always to eliminate the hazard, increasing the ease with which consumers can use a guard is a reasonable second choice.

Part II - Exploration of New Tip-Restraint Systems

Demonstration Environment

To address the primary goal of this project, staff built a freestanding, two-sided room consisting of adjacent 6-foot-high walls constructed of 2-inch by 3-inch pine studs and drywall. One wall was built with 3/8-inch drywall, and the other was built with ½-inch drywall. The walls were bolted to a typical plywood subfloor supported by 2-inch by 3-inch pine stringers. Studs were spaced 16 inches apart on center. Both walls were trimmed with a typical pine clamshell baseboard, installed with number 4 finishing nails, and a base strip of quarter-round pine. Walls, trim, and floor were painted with a single coat of PVA primer and a single coat of latex, semi-gloss paint.

Staff evaluated the various hardware anchoring strategies on a secondhand 5-drawer dresser and a secondhand television cabinet. Both furniture items were purchased from a local thrift store. Both pieces of furniture were primarily made of wood and are believed to be typical of what is found in many homes. Scraps of a low-cost berber loop rug with ½-inch-thick foam carpet pad were also placed under the furniture's feet to estimate the effect of carpeting on the furniture's stability, when appropriate.

Figure 1. The dresser used to evaluate new tip-restraint ideas is shown here saddled with two 25-lbm steel blocks.

New Tip-Restraint Systems

The following types of potential anti-tip hardware were evaluated:

A. Drywall anchors (2 sizes)
B. Self-tapping toggle bolts (2 types)
C. Bent wire picture frame hooks (3 sizes)
D. Plastic adhesive hooks (2 types)
E. Baseboard wedge (a prototype design made by staff)
F. Baseboard hook (a prototype design made by staff)
G. Folding drawer legs (a prototype design made by staff)

The goal of this project was to demonstrate the strength of both readily available products and inexpensive prototype designs that were considered by staff to be installed easily without tools. This was an exercise in proof-of-concept. As such, force measurements presented in this section were only collected once. There were not multiple trials to validate their accuracy. However, staff believes that the results are sufficient to establish anecdotal evidence and establish a baseline for future comparisons. It was also beyond the scope of this project to determine optimum design details for a furniture anchoring system. Parameters for these details can be studied in the future.

A. Drywall Anchors: Staff modified two types of drywall anchors to allow them to be installed without power tools. The drywall anchors were designed to be tightened with a screwdriver, but staff inserted a metal t-shaped bar into the head of the anchor to make a handle for twisting. This eliminates the need for a screwdriver and could be included in the package provided by manufacturers. This is similar to the hexagonal Allen keys that come with many other consumer products that require assembly. Our prototype handle could be removed simply by pulling it out of the anchor’s head, but it could be permanently affixed without trouble. Many shapes of handles would be suitable, but the t-shape was simple to make and effective.

Figure 2. The drywall anchors were able to be inserted with two pieces of readily available metal rods welded together.

The furniture tether strap was attached to the anchor using a picture hanger accessory that was packaged with one brand of the anchors. The hanger consists of a metal plate with a hole sized for the head of the anchor and a metal hook that protrudes about ¼ inch from the plate. Staff installed these hooks upside down to allow for a furniture tether to be looped onto the hook and pulled from above. One anchor was 1 ¼-inch long and ½-inch in diameter. The other was slightly longer, measuring 1½-inches long and 9/16 of an inch in diameter. Both were easy to install by hand. Once the paint and paper on the drywall are penetrated, the anchor draws itself into the drywall with a turn.

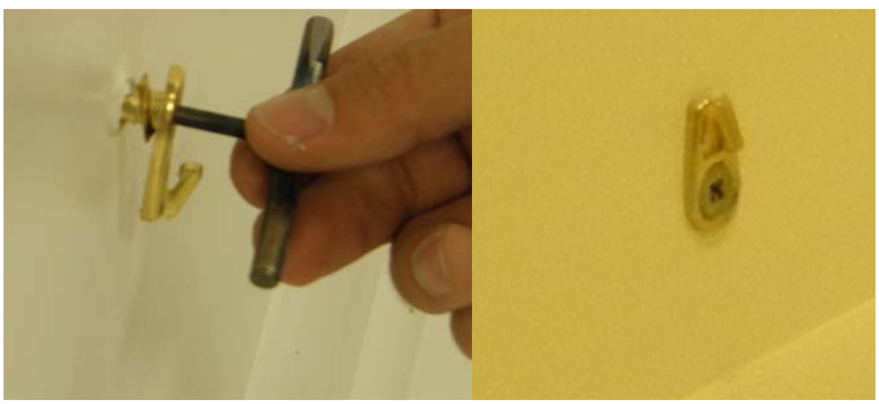


Figure 3. The drywall anchors were used to fix upside-down metal hooks to the wall.

The anchors were tested by pulling on them with a metal wire and a force gauge, starting the pull in an upward direction close to the wall and then rotating the angle of force away from the wall to about 45 degrees from the wall. For several seconds both sizes of anchor withstood a 50-lb. pull at angles from about 15 degrees from the wall to about 45 degrees from the wall. The exact number of seconds was not recorded. When the pull angle reached about 40 degrees, the hook plate began to move and dent the drywall. The hook plate only pulled away from the wall about 1/16-inch and did not break loose of the wall. If a wider hook plate had been used, the force would have been spread over a larger area and would have allowed the drywall to withstand even higher forces without any deformation. In normal use as a furniture anchor, the anchor would only need to withstand forces applied between 5 and 20 degrees from the wall. The anchors that staff examined easily withstood 50 lbs. at these low angles. Both thicknesses of drywall were examined and were able to provide adequate support.

B. Self-tapping toggle bolts: Two different designs were compared and both kinds were manufactured with one or more pointed barbs on one side of the toggle for boring through drywall without a drill. Both brands required a screwdriver to tighten a bolt in the toggle; however, the bolt head could be modified to allow the consumer to grip them so that no tool is needed. Installation requires the consumer to push and twist the pointed end of the toggle into the drywall (see Figure 4).

One of the brands required an additional step of setting the toggle. This was achieved by breaking off two plastic arms that were affixed to rotate the toggle into position once it cleared the wall. After the arms were removed, a bolt could be threaded into the anchor and tightened with a screwdriver. (see Figure 5).

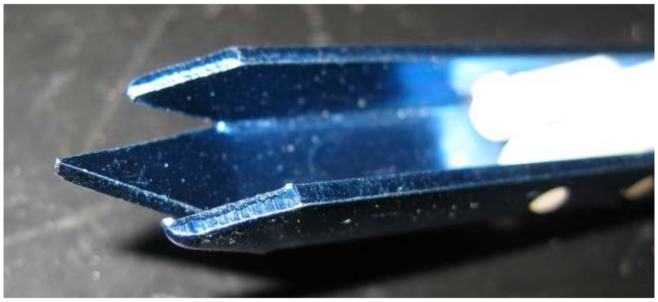


Figure 4. This is a close-up of the barbed ends that allow the bolt to penetrate the wall.

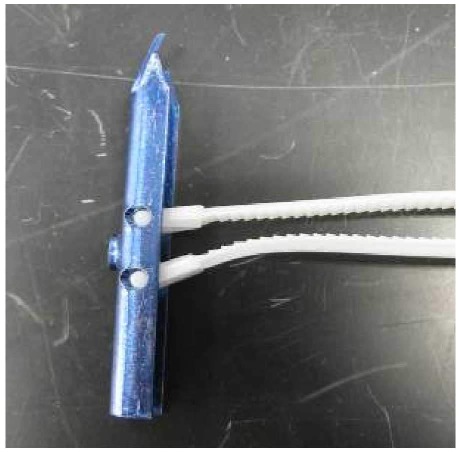


Figure 5. The white plastic pieces allow the user to manipulate the toggle location before being broken off for the installation of the bolt.

In the other product, the bolt rotated the toggle into position when it was inserted (see Figure 6). As with the drywall anchors, the bolts in these anchors could be modified to allow hand tightening. These anchors also needed to be supplemented with a hook to attach the tether (see Figure 7). Staff used flat metal hooks with a hole for the bolt in their center.

Figure 6. The metal toggle bolt has already been installed in this photo. The view is from the back of the drywall.

Figure 7. A metal hook was used in conjunction with the metal toggle bolt of Figure 6. This is a view from the front of the drywall, the interior of a room.

Once tightened, the hooks provided the same function as the metal plates used with the drywall anchors. Both types of self-tapping toggle bolts held up to a 50 lb. pull force at angles from about 15 degrees from the wall to about 45 degrees from the wall. The number of seconds was not recorded and the anchors were not tested to failure. No noticeable deformation of the drywall or anchors was observed in both walls of the demonstration environment.

C. Bent wire picture frame hooks: Constructed of a 6-inch to 8-inch long, curved metal wire, these products are easily pushed into drywall to hold small frames on the wall. See Figures 8 and 9. The tip of the hook is machined into a bevel so that its point can bore easily into drywall. Very little force is needed to push the wires into the wall; it is a one-handed operation. The hooks were installed as intended, except that they were inserted into the wall upside down to hold the furniture tether in an upward pulling direction. These products did not need any modification to test; but in use as a furniture tether, they would need to be modified to hold a tether securely, without falling off. A simple loop, rather than a hook shape would work.

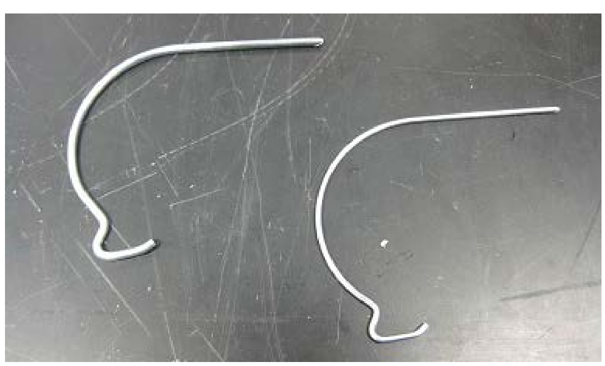


Figure 8. Bent wire picture frame hooks.

Figure 9. The image on the left shows two installed hooks from the interior of the room. The bulk of the anchor is obscured by the drywall. The image on the right shows the reverse view of three separately installed hooks.

Staff tested two sizes of hooks, each made with a different gauge of wire. The larger wire was 0.105 inches in diameter, the smaller wire was 0.071 inches in diameter. Staff only tested these in ½-inch-thick drywall.

The thinnest wire held about 20 lbs. before flexing out of place. The thicker hooks held up to 25 lbs. This type of hook would probably not hold up to 50 lbs., unless made significantly thicker. These hooks were easy to install and the simplest design of all of the options evaluated, consisting of just a bent wire. If more holding force were needed, several hooks could be used in parallel to increase the holding power of the anchoring system. This would necessitate additional instructions to avoid asymmetrical loading. The hooks also have the advantage of only making small holes in the wall. Small holes in drywall are easier to repair than large holes once the anchoring system is removed.

D. Plastic adhesive-backed hooks: These products are intended to hold items without the need to damage a wall with a penetrating fastener. Two brands were examined. One type had a two-piece adhesion system that required consumers to peel and stick a plastic base layer to the wall before sticking the hook on top of the base. The other type was removable, using hook and loop fasteners to allow the hook to be removed from the layer that was glued to the wall. Staff installed the hooks as intended, but upside-down to facilitate an upward pull.

Figure 10. The plastic hooks are shown adhered to the drywall.

Both products were able to withstand a 20-lbf pull from about 15 degrees from the wall to about 45 degrees from the wall for several seconds without any noticeable deformation of the plastic adhesive. Greater forces started to deform the plastic and the testing was stopped. The longevity of the glue is unknown. This method of anchoring does not usually mar the wall and is quick and easy to install. As with the picture frame hooks described above, the plastic adhesive hooks would be better designed for use as anchors if the hooks were closed loops that would not allow the tether to slip off. We did not ascertain the expected lifespan of the adhesives, but the use of adhesives may be important for temporary installations that consumers could rely on until they can get a more permanent solution installed.

E. Baseboard wedge: Staff invented the baseboard wedge and made a prototype using steel sheet and readily available parts. It is about 3 inches wide, 4 inches tall, and 1.5 inches deep and is designed to be kicked with a heel under typical wood baseboard trim. It is a thin metal wedge with widely spaced teeth that allow it to be inserted around unseen tacking nails. The furniture tether was attached to a D-ring on top of the wedge, but many other types of tether attachment points would work as well. See Figure 11.

Figure 11. The metal baseboard wedge.

A staff member wearing men's leather dress shoes kicked the wedge under the test fixture's baseboard using just the heel of one foot. About five light taps were applied before the wedge stopped sliding. The wedge slipped under the molding without breaking it. The application would theoretically be the same with carpeting, but it was not evaluated here.

Figure 12. A front and side view of the wedge as installed.

The baseboard wedge held 50 lbs. from both a vertical direction and 45 degrees from the wall without moving the baseboard or shoe molding. It would be possible to hold a greater force. The baseboard lifted slightly when the wedge slid under, cracking the paint in the seams between the boards, but the baseboard was not marred by the wedge's installation. Staff believes that the wedge could be made of thinner materials with no loss of functionality.

F. Baseboard hook: This prototype, also invented and constructed by staff, consists of a rigid 0.1 inch wire with a hook that is tapered flat like a chisel. The tapered hook is thin, but rigid. It was pushed behind the baseboard from the top, sliding between the baseboard and the wall. The user then rotates the handle to be flat against the wall. This will rotate the hook so that it catches beneath the bottom edge of the drywall or paneling on the wall. Drywall and paneling typically have a ¾ to 1-inch-wide gap next to the floor, to allow the wall to settle or flex over time. This anchoring strategy capitalizes on that small gap. The hook has the advantage of not puncturing the drywall. Additionally, the hook can be removed and reused without causing any damage to the wall. Many kinds of tethers could be affixed to the hook in a variety of methods.

Figure 13. The baseboard hook.

G. Folding drawer legs: This prototype, also invented and constructed by staff, consists of metal legs that are fastened to the front edge of the lower surface of the bottom drawer of a chest or dresser. The legs are long enough to reach the floor when the drawer is pulled out. They fall down on a hinge as soon as the drawer is opened and would prevent the dresser from tipping forward by effectively moving the front feet of the dresser to the front of an open drawer. This relocation of the fulcrum point, completely changes the stability of the dresser. See Appendix A for more information. If the body of the dresser began to tip, the drawer would jam upward against the top of its compartment and either arrest or impede the falling body.

Figure 14. The folding legs are featured.

As long as the sides of the bottom drawer are tall enough to catch the dresser chassis, the folding legs will effectively prevent tipping by moving the fulcrum from the front dresser legs to the front of the bottom drawer. To put the drawer back in, consumers must fold the legs back up to the bottom of the drawer. The prototype was quite heavy, made from readily available metal; however, a retrofit using peel-and-stick adhesives to hold the legs to the drawer would be possible. This design has the advantage of being fast and easy to install and does not mar the wall or baseboard. The primary disadvantage is that the bottom drawer must be pulled out to increase the stability of the dresser as opposed to any of the higher drawers. The second disadvantage is that the consumer must fold the legs to close the drawer each time it is used. Another disadvantage is that the legs, as currently conceived, are not universal to all bottom drawer heights. However, staff believes this would be a very promising concept if the legs could be activated automatically by the opening or closing of the drawer.

Part III - Exploration of Ancillary Tipping Phenomena

Tether Tension Testing

After demonstrating that the anchoring strategies were relatively easy to install and reasonably strong, staff tested the tension that could be produced on an anchor when a dresser was overloaded at the drawer, as would happen during an incident involving children climbing up the drawers of a dresser. Staff put a digital force gauge attached with wire to the wall on one side and attached to a dresser on the other side of the gauge. When the dresser tipped, the force exerted on the tether was shown on the gauge in pounds.

The anchor used was a 1 ½-inch drywall anchor positioned 18 inches from the floor. The tether was affixed to the furniture with a cleat screwed into the unit about a ½-inch down the back from the top surface. The dresser (49" tall, 36" wide, and 18" deep) was positioned on the floor without carpet about 4 inches from the wall. The tether was tightened so that there was no slack, and weights were placed on the open drawer. With 100 lbs. of weight in the bottom drawer, see Figure 15, the tension on the tether was only about 8 lbs.

Figure 15. The attachment point to the wall is highlighted.

With carpet squares and pads under each leg of the dresser, see Figure 16, the tension on the tether only increased to about 10 lbs. Notably, the ASTM standard for furniture (ASTM F3096) requires that anchors provided with dressers hold a minimum of 50 lbs. of force.

Figure 16. Small squares of carpet and padding were used to simulate a carpeted environment.

Tether Slack

Common furniture anchoring systems have a way to adjust the length of the tether. This is important because a slack tether will allow the furniture or television to wobble in place before fully tipping over. After the tipping motion has begun, there will be an impulse force on the tether that may exceed the tether’s rated load capacity due to the momentum of the falling furniture. Several options exist for ensuring that tethers are installed with little to no slack. One option is to loop the tether back on itself with a fastener that can be adjusted, such as a cord lock, ladder lock, or other compression fitting. Another option is to use a friction tensioner, such as those used on tent guy lines.

Perhaps the easiest way to take up slack in a corded tether is to install a cleat on the furniture that allows the end of the tether to be wrapped around two or more posts. The adhesive-backed hooks discussed above could be improvised to achieve this goal. They could be placed end-to-end, with their hooks opening in opposing directions. See Figure 17.

Figure 17. An improvised cleat would serve as the connection point to furniture. In this photo it has been wrapped in a figure-eight to remove the slack from a corded tether.

Hard Flooring vs. Carpet

Staff attached a wire cord and force gauge to the front of the empty dresser and the empty media cabinet. The same demonstration environment described in Part II of this report was used. The freestanding furniture units were pulled to their respective tipping points, both on a hard floor and on the carpet pads, both with and without a television on them.

As freestanding units, both the dresser and the media cabinet required between 13 lbs. and 18 lbs., respectively, to tip without the weight of the television.

The dresser was loaded with a 39-lb. cathode ray tube television. The pull force needed to incite a tip-over incident was only about 2 lbs. to 4 lbs. more than without the television.

The media center was loaded with a 130-lb. cathode ray tube television. The pull force needed to incite a tip-over incident was only about 3 lbs. to 7 lbs. more than without the television.

The carpet padding had insignificant measured effects on the forces needed to tip the furniture in a single action. However, it was observed that the carpet padding did allow the furniture to wobble more freely when the furniture was pushed than when the furniture was on the hard floor. In a worst-case scenario, a child could rock the furniture backward to slacken the tether, allowing an impulse force to build and be released on the foreward swing.

Part IV - Discussion and Recommendations

Layers of Protection

The primary goal of this project was to demonstrate the feasibility of tip over restraint systems that do not require tools to install. In the course of that exploration, staff investigated and hypothesized several other factors that could contribute to the hazard pattern. Staff understands that this is a multi-faceted problem that will need several incremental steps in design, appropriate use, consumer education, and consensus oversight before the rate of injury will significantly decrease.

With respect to manufacturer's design, staff believes that attaching one end of a tip over restraint system to their furniture before it leaves the factory has several advantages for injury prevention:

1) Getting attention – A factory-installed tether is a good attention-getting tool. Consumers will be forced to observe the thing hanging from the back of their furniture. It is unusual and conspicuous. Getting attention with a free-swinging object will likely be more effective than a commonplace warning label.

2) Educating consumers – A factory-installed tether is a good education tool. It provides a conspicuous surface for tags that have warnings and instructions. Consumers will be more likely to read such attached warnings because they are in an obvious and unusual place and the information will be available to future users, unlike unattached instructions that often are discarded.

3) Saving time – A factory-installed tether can save time. It can have one or more tool-less anchoring hardware alternatives already affixed to it so that all consumers need to do is push the unit close to the wall and select their preferred anchor.

4) Immediacy – Having the option to use adhesive-backed anchors and tethers could provide temporary solutions that will suffice until more permanent anchors can be installed.

Furthermore, tool-free anchoring strategies will provide ease of installation benefits once the consumer has the furniture in their home. Nondestructive anchoring systems provide alternatives for consumers who do not want to damage their walls. The goal is to encourage consumer use and discourage misuse by streamlining the anchoring process to the furniture and providing adequate options that the consumer will use on the other end.

With regard to appropriate use, staff has demonstrated that the location of attachment to the wall can significantly impact the force required to incite a tip over. By fixing a tether to the wall at a position lower than the attachment point on the furniture, the alternative anchoring systems were all capable of stopping the test furniture from tipping. This was shown even with the standard 50-lb. weight on the edge and another 100 lbs. inside the open drawers.

It should be noted that the addition of a television on top of another piece of furniture did not significantly increase the forces required to incite a tip over. However, there are three reasons this fact may provide a false sense of security. First, adding the television will raise the collective center of gravity and decrease the angle required for a tip-over. Second, small tipping angles of the furniture could lead to the television sliding falling forward off the furniture, even if the dresser does not tip over. Third, the potential energy in the system is significantly increased with the additional mass of the television. Both the dresser alone and in combination with the television have the same triggering force, but the combination releases more energy on the victim.

Carpeted environments exacerbate the potential for a tip over incident. The single-motion force required to incite a tip over did not increase with the presence of carpets. But just like the addition of a television, this fact may provide a false sense of security. Staff is concerned that carpets would make it easier for a piece of furniture to be rocked back and forth past its tipping point.

Staff believes that furniture tip-over injuries and fatalities could be reduced with a well-informed consumers and easy to-use designs. Staff recommends that manufacturers, retailers, standards development organizations, and consumer advocates, as a part of their future injury prevention campaigns, consider tool-free anchors and non-destructive anchoring strategies for furniture, appliances, and televisions.

Works Cited

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APPENDIX A

Mechanics of Furniture Tipover

Freestanding Furniture

Furniture tip-over incidents occur when the magnitude of the sum of the moments[5] about any point is greater than zero. Two-dimensional analyses are sufficient to describe the tip-over mechanics of a piece of furniture with a rectangular or square base. Figure 1 shows a free body diagram of a typical chest of drawers. When a weight is applied to an open drawer, there is a tendency to rotate (or tip) the chest at the front corner, or Point A in the figure. The furniture will not tip, as long as the sum of the moments about Point A equals zero.

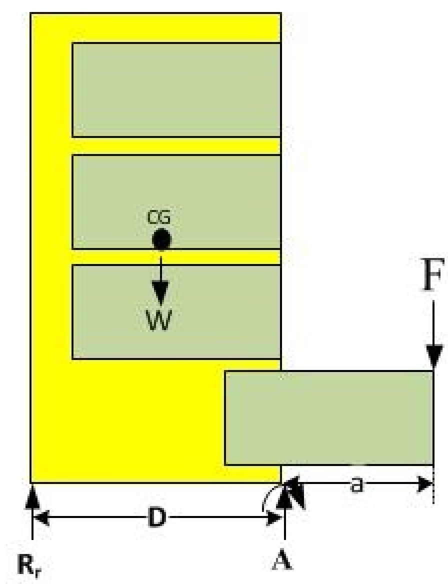

Figure 1: Freestanding Chest of Drawers Subject to a Tipping Force

The sum of the moments about Point A (**ΣM_{A})** is given by Equation 1.

$\Sigma M_A = Fa + R_rD – WD/2$, where: (1)

F = the force applied to the extended drawer;
a = the distance from Point A to the axis of force F;

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[5] A moment is a force acting at a distance and is expressed in inch-pounds, kilogram-meters, or equivalent units. A moment on a body tends to rotate the body about a point.

R_r = the reaction force of the floor on the rear of the chest;
D = the depth of the chest;
W = the weight of the chest and its contents; and
Positive moments are clockwise.

For simplicity, we assume that the weight of the chest is very near the center of the depth of the chest. Thus, the moment arm for the weight at point A is D/2. Because the reaction force of the floor on the front of the chest (not shown) passes through point A, the front force moment arm length is zero, and does not contribute a term to Equation 1.

When $\Sigma M_A = 0$, the furniture is not tipping, and the terms can be rearranged as shown in Equation 2:

$$\mathbf{WD/2 = Fa + R_rD.} \qquad (2)$$

At the point of instability, where the force F is about to tip the chest, the reaction force R_r approaches zero. In this circumstance, the sum of the moments about Point A is shown in Equation 3.

$$\mathbf{WD/2 = Fa.} \qquad (3)$$

From Equation 3, we can make the following observations:

- The heavier the dresser, the greater the force required to tip it over;
- the deeper the dresser, the greater the force required to tip it over (assuming the distance *a* remains constant); and
- the height at which the force F is applied does not affect the propensity of the chest to start to tip. If the force F were applied to the top drawer, instead of the bottom drawer, the propensity to tip over is unchanged. In other words, there is no vertical dimension in Equation 3.[6]

Effects of Carpeting

If the furniture is not on a flat surface, the dimensions *a* and *D/2* can change slightly. For example, if a tall chest of drawers is on a carpet, and the rear legs rest on the incompressible tack strip used in typical wall-to-wall carpeting installations, the front legs will compress the carpet

[6] However, once the furniture begins to tip, the vertical locations of the tipping force F and furniture weight W do matter. The higher up the forces F and W, the greater their moment arms increase (in the case of F) or decrease (in the case of W. The tipping moment caused by F will increase more rapidly, and the restoring moment caused by W, will decrease more rapidly, as the furniture begins to tip.

slightly, tipping the chest forward. This tipping forward has the effect of increasing the distance *a* and decreasing the distance *D/2* in Equation 3. Additionally, the reaction force R_r is slightly decreased, and the chest of drawers weight *W*, moves slightly forward.

Factors affecting the magnitude of the depression in the carpet include carpet resilience, padding materials, and time. With most furniture, the effects of carpeting should have negligible effects on the distances, but the presence of carpeting and padding could become influential in describing the potential for tip-over incidents with especially lightweight, tall, or thin furniture.

Tethered Furniture

Adding a tether increases a piece of furniture's resistance to tipover. As shown in Figure 2, three other dimensions are introduced with the addition of a tether: the distance the furniture is moved away from the wall; the height above the floor at which the tether is attached to the wall; and the height above the floor at which the tether connects to the furniture. Assuming that the tether is a flexible cord or cable, the tether is only capable of carrying a tensile force. The sum of the moments about Point A is given by Equation 4.

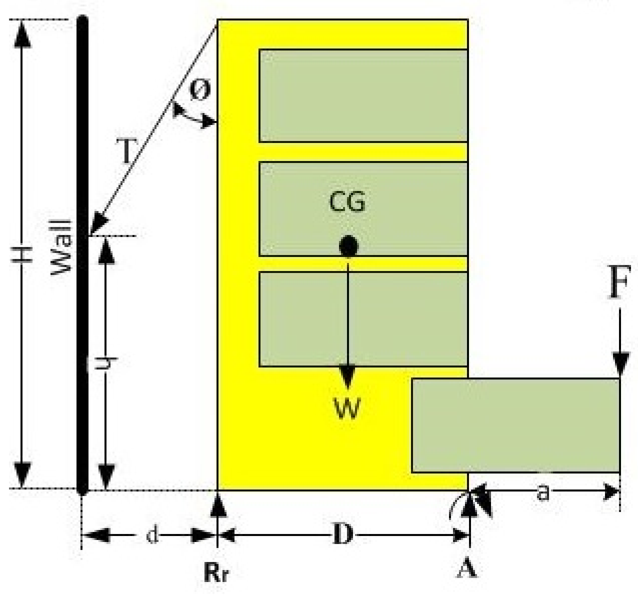

Figure 2: Tethered Furniture

$\Sigma M_A = Fa + R_r D - WD/2 - TD\cos(\phi) - TH\sin(\phi)$, where: (4)

F = the force applied to the extended drawer;
a = the distance from Point A to the axis of force F;
R_r = the reaction force of the floor on the rear of the chest;
D = the depth of the chest;
W = the weight of the chest and its contents;
T = the tensile force in the tether;[7] and
ϕ = the angle to the vertical the tether makes.
It is assumed that the moment arm from the weight of the chest to point A is very close to D/2.

The angle ϕ is determined by applying Equation 5:

$$\phi = \tan^{-1}[d/(H-h)] \text{, where:} \quad (5)$$

d = the distance from the wall to the rear of the chest of drawers;
h = the height above the floor at which the tether is attached to the wall; and
H = the height above the floor at which the tether is attached to the chest.

The critical condition for Equation 5 is at the point where the furniture resists tipover only due to the tensile force in the tether. In this case, the force $R_r = 0$. With these conditions, Equation 4 simplifies to:

$$F(a) = WD/2 + TD\cos(\phi) + TH\sin(\phi). \quad (6)$$

Equation 6 can be rearranged to solve for the tension in the tether as a function of the tipping force F:

$$T = \frac{Fa - WD/2}{D\cos(\phi) + H\sin(\phi)}. \quad (7)$$

Substituting for ϕ gives:

$$T = \frac{F(a) - W(D/2)}{D\cos(\tan^{-1}[d/(H-h)]) + H\sin(\tan^{-1}[d/(H-h)])}. \quad (8)$$

[7] Note that if the tether is slack, the tension *T* is zero, and Equation 4 is the same as Equation 1. In this circumstance, the tether only helps stabilize the chest of drawers after tipping has eliminated the slack.

Equation 8 can be applied to two particular conditions. First, if the factor d/(H-h) is very small (the furniture is very close to the wall, and/or the tether is attached very near to the floor).[8] Equation 8 simplifies to:

TD ≈ Fa – WD/2. (9)

The tensile force T becomes a mostly vertical force with a moment arm of D. The forces exerted on the wall and furniture connections of the tether are mostly shear forces.

Second, if the factor d/(H-h) is large, (the furniture is far from the wall, and/or the tether is attached to the wall very near the same height as its attachment to the furniture), Equation 8 simplifies to:

TH ≈ Fa – WD/2. (10)

The tensile force T becomes a mostly horizontal force with a moment arm of H. The forces exerted on the wall and furniture connections of the tether are mostly tensile forces.

Discussion

Force, weight, and geometry are the dominant factors in determining whether a piece of furniture will tip, and under which circumstances. For a given piece of furniture, its height and depth are fixed quantities. Its weight can vary, based on what is stored inside the furniture. The use of a tether has the possibility of greatly increasing a piece of furniture’s resistance to tipping, depending on its attachment points, its tensile strength, and the type of connections made to the furniture and the wall or floor.

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[8] Both conditions assume that the tether is attached to the wall at the same height or lower than its attachment to the furniture. Attaching a tether in tension to a wall above its attachment point on the furniture would tend to increase the possibility of tipping for furniture with a low aspect ratio. When the furniture tips, the tether will go slack until the rear of the furniture tips far enough to stretch the tether to its full length.